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Teaching basic metrology concepts.

A multiple intelligences didactical approach

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Abstract

The adequate teaching of some metrology basic concepts at the senior high school level, may offer interesting results when used for the development of the student´s scientific skills. But inside the classroom, the students have different learning styles (for example: visual, aural, kinesthetic etc.). How to teach issues like the SI base quantities/units within these learning diversity in the same classroom? As a part of an educational research project and based on the contributions of Howard Gardner and others in the area of Multiple Intelligences (MI), a didactical strategy for teaching SI units using the so called ”learning-stations” will be proposed.

1. Why to teach basic metrology concepts at senior high school level?

As a fundamental part of the science language, we ought to recognize that metrology concepts play a very important role when we try to depict reality through physical quantities. A number without units, may be enough for a mathematical analysis, but for experimental sciences, it has any relationship with the natural world. Any number has to be followed by units for considering it a physical quantity. At senior high school level at Universidad Nacional Autónoma de México (UNAM) in Mexico City, the lack of specific didactical approaches for teaching physical quantities and other metrology concepts, may have led to important problems in the student´s Physics learning process. Some of the problems and advantages of including this topic in the official study programs are:

a) Weak understanding of physical quantities lead to conceptual failures. May be that is the reason why, by problem solving, many students arrive to correct numeric results but without knowing what do these numbers physically mean [10].
b) Understanding physical quantities from a constructivist point of view, may help students to understand basic and complex physics concepts.
c) Teaching physical quantities from a constructivist point of view, is a powerful tool for developing scientific skills like analyzing physical problems and phenomena.
d) Confusing concepts potentially may get clearer. Knowing how physical quantities may be figured out through their units, may help to differentiate confusing concepts. For example: mass [kg] ≠weight [N]; current [A] ≠ power [W]. May be the student doesn´t understand deeply the difference between mass and weight but only guided by the units from each quantity, students may realize that we are speaking about two different concepts.
e) Developing dimensional analysis skills can provide a powerful tool for understanding science concepts

2. Theoretical framework.

For developing the didactical strategy we propose, we need to support our findings on the contributions of Howard Gardner, Dunn&Dunn and some game-based-education theorists like Huizinga, Prensky and Dave Moursund.

Gardner´s multiple intelligences (MI): Since the publishing of Howard Gardner´s *Frames of Mind: The Theory of Multiple Intelligences* in 1983, many other authors have written about the educative consequences of this vision. Gardner considers intelligence not as a unitary concept that involves different capabilities, but a net of interrelated capability sets that may be used in different ways, together or separate and that, from learned experiences in the past, let the individual to successfully respond to new situations and problems.

Assuming this definition of what intelligence is, Gardner establishes that the people´s intelligence is the result of activating or not activating certain intelligence potentials. This activation is strongly related to the specific culture around an individual, the chances offered by this culture and the decisions taken by the individual, the family, the teachers and other social actors.

Initially Gardner lists 8 different intelligences: Naturalistic, intrapersonal, interpersonal, visual-spatial, musical, bodily-kinesthetic, verbal-linguistic and logical-mathematical. A person may tend to solve problems using one or even more than two of these intelligences classification. The number of intelligences has increased since then.

Rita and Kenn Dunn´s learning styles proposal (LS): although there are a variety of theorists that speak about the different manners an individual can learn, the Dunn&Dunn is the most widespread focus within the educational world. Dunn&Dunn adopt the idea that people have different ways to assimilate knowledge (different learning styles). They say that teachers need to use didactical strategies that benefit every student´s learning style and this can be achieved by redesigning the classroom, developing small-group techniques and the use of learning stations or differenced instructional areas. These learning styles are well connected with the multiple intelligences view. Each person may possess multiple intelligences, but he/she tends to use one learning style over the others. Other authors also propose the need of diverse activities that activate the so called multiple memory pathways to get a better knowledge retention in mind, a variety of activities activates mental pathways related with visual, auditive, kinesthetic, which reinforce a concept learning.

Game based learning: since the writing of Johan Huizinga´s *Homo Ludens* in the beginning of the 20th century the literature concerned with the use of games in education grows every day. Playing games for learning a topic has many advantages, according to Marc Prensky when speaking about games: They are a kind of fun, what means enjoyment and pleasure to us. They are a kind of play, what means intense involvement. They have rules, which means a structure. They have goals, which means motivation to us. They are interactive, so they lead us to action. They feedback us, so we learn. They have conflict/competition/challenge/opposition, what means adrenaline to us. Their problems need to be solved, so we need to be creative. They make us to interact with others, and they have representation and story, so that means emotion to us. Duit [16] also rescues the fact that ludic teaching dynamics, apart from achieving motivation, also may have an emotional contribution to affection and the commitment needed for a meaningful learning.

In his book *Introduction to Using Games in Education: A Guide for Teachers and Parents,* Dave Moursund, adds other educational goals possible with games:

a) Learning to learn and to help others learn; learning about one’s strengths and weaknesses as a learner.
b) Learning to work both individually and collaboratively with a team on a large, long, challenging project.
c) Learning for transfer of learning.
d) Learning to improve one’s creativity.
e) Learning that helps increase one’s level of cognitive development and cognitive maturity

The importance of teaching through games, increases in the case of physics, since several studies show that senior high school students tend to get demotivated about this science subject when they do not find any relationship between real life and the physics knowledge. So, the games we need for motivation, also we need them to be contextualized [10, 11, 12, 13, 14, 15]

The didactical problem with the Multiple Intelligences approach.

When trying to apply Gardner´s approach to our classroom, we find difficulties:

a) Diagnosis to identify a dominant learning style in the classroom is not easy, especially because one person may dispose of more than one learning style
b) Designing a lesson according to a dominant learning style, may be very demanding for the teacher and may be discriminatory against students that have different learning styles (inclusion problem), e.g. a kinesthetic student is assessed only through a reading activity. This strategy can be demotivating as well as boring to some students, which means, it becomes anti-pedagogic.
c) Paying attention to only one or two learning styles when designing a lesson may be not learning-efficient, because knowledge assimilation needs reinforcement and the activation of different synaptic ways in the brain
d) Learning a concept needs some rehearsal but lesson´s time is limited
e) Group size is a hurdle: In Mexico and other Latin-American countries, typical senior high school groups rank from 30 to 60 or even more students. This situation worsens the above mentioned didactical hurdles.

As a possible solution to these didactical problems, Dunn&Dunn propose the use of learning stations. To solve the inclusion problem of MI, the classroom is divided into *learning stations*. From station to station the involved activities vary to stimulate different learning styles and intelligence types. At each

station a concept may be partially learned or reinforced. Learning stations may provide the means for differentiated instruction (Binnendifferenzierung).
Using learning stations as a didactical strategy is a very popular resource at german schools [17]. Although this proposal may solve the inclusion problem, learning stations may still have some deficiencies:

a) Time limitation may still be a hurdle
b) The strategy may not be effective if it is not motivating to the students.

3. Our solution: ludic learning stations approach

Facing the didactical problems exposed by the multiple intelligences and learning styles theories, and considering the advantages of game-based learning, we propose a strategy, a ludic learning stations approach for strengthen the concepts behind the teaching of physical quantities and their SI units. This proposal has the following features:

a) The classroom will be divided into 5 learning stations where different learning styles are stimulated. The objective is to give a solution to the inclusion problem exposed above, so we need to develop strategies that give students the chance to learn according to the intelligence type/learning style they are used to.

b) Similar contents, that is base/derived quantities and units, are worked inside each learning station. The learning stations approach can be applied either by activities that help to learn partial concepts of a whole topic at each station or as we propose here, by activities that help to learn the same contents in different didactical ways. We selected this last approach, because we need the students to rehearse the knowledge about physical quantities and also is desirable that they could transfer this knowledge into different contexts.

c) The selected activities at each learning station are designed to be ludic and entertaining for the students, as we exposed about game-based learning, this may help to inject a high motivation dose to the didactical strategy.

d) The whole time students will participate in couples, in such a way to speeding up the dynamics of the whole learning stations strategy and letting the students to realize the advantages of collaborative work between them.

e) A very important aspect of this strategy is that all students must go through all the five learning stations in order to give them the chance to assimilate knowledge not only through the learning style they are used to, but also to get it in other ways, what accomplish with the requirement of knowledge rehearsal written lines above. Considering this, all couples must participate at least once in each learning station and only 4 couples maximum are allowed to occupying one station simultaneously.

f) As we may infer, there is no learning-stations specific order to be accomplished, and also we have the problem of how to control which activity has been already accomplished by each couple. A solution to this problem, could be giving a control sheet to each couple with the list of activities to be done and every time the couple has already finished activities at a learning station, the teacher can seal or sign on the corresponding space on the control sheet.

g) The 5 learning stations include the following activities: Station 1-Bingo: each student couple has a bingo style board, with 9 squares. Each square has the name of a physical quantity (force, length, time etc.). The conducting student will be designated according to the last name´s alphabetical order of all the station participants. This student has a bunch of cards aleatory mixed, each with an image depicting a physical phenomenon/action and a sentence describing any physical aspect and units related with the image. For example, the image shows a running car and the sentence says “A car runs at 60 km/h”. The conducting student shows aleatory the cards to the others and the participants must infer if the image and sentence showed are related to any of the quantity names on their bingo board. In our example, the board square with the name “velocity” may be selected. Wins the first couple that finishes with selecting all squares on its board. Station 2-Memory: similar to the traditional game, the participants must try to collect card pairs similar to each other, but in this case a card pair is made by and image with sentence and the name of the quantity it represents, just the same pairing criteria as by the bingo game. Wins the couple that collects the higher amount of card pairs. Station 3- Domino: Instead of playing with seven numbers, we play with the seven base quantities. Each of the 28 tokens is divided, one half has the physical quantity name and the other half, is an image with sentence and units. The pairing criteria for placing the domino tokens is the same as by the games described previously. Station 4-Measuring instruments: on the table the students have different measuring instruments (rulers, chronometers, thermometers, test tubes, flasks etc.) There is a list of different measuring activities. The students must select three activities that involve each a different physical quantity. The students write down their results and draw the instruments they used on the control sheet. Station 5- Phenomena analysis: In this station the students have diverse objects on the table that involve physical phenomena. The students must write down on the control sheet a list of 5 or 6 physical quantities they observe are present on one selected phenomenon and their as well as the possible measuring units for such quantities.

h) As we said when speaking about the learning stations theory, time may be a hurdle if activities are not well defined neither motivating enough for the students to be accomplished. Also there is some risk that students prefer to remain or repeat participation at a specific learning station, and forget to participate at the others. To solve the time problem and speed up the whole dynamics, we suggest to give a rally or contest format to the ludic learning stations lesson. The winner couple will be the first to participate at least once in each 5 learning stations and this can be controlled with the control sheet. If the teacher considers that there is enough time to complete a second round or that the winner couple will be the first on participating at least twice in each station, it can be done. According to our first experience with this proposal, the winner couple can make a whole learning stations round in approximately 40 minutes and the whole students group needs a bit more than one hour to complete it.

i) After finishing the learning stations dynamics, we propose to activate all senses with a musical activity, an activity based on a song (The Units Rap) with an understandable explanation of the seven base quantities and their units, that let the students to detonate their creativity and simultaneously helps them to remember the base quantities that build more complex physical concepts and that are considered when executing dimensional analysis. This is a reinforcement activity that consist on dividing the group into seven teams, each team will get in charge of singing the verse corresponding to one specific base quantity/unit. The refrain will be sung by the whole group each time a verse has been finished when interpreting the Units Rap. After showing the song to the students and letting them some time to rehearse, we can conduct a contest, where the team with the best choreography and creativity when singing their corresponding verse will be the winner. Besides of its mnemonics character, this closing activity stimulates the student´s musical and kinesthetic intelligences.

As we can see from the learning stations dynamics description, the activities are planned to stimulate different intelligence types and are aimed for giving students a chance of using different learning styles. The five ludic learning stations proposal stimulate 6 of 8 intelligences types:

a) Bingo (visual-linguistic)
b) Memory (visual-linguistic)
c) Domino (visual-linguistic-logical)
d) Measuring instruments (kinesthetic-logical)
e) Analyze physical phenomena (kinesthetic-visual)
f) Always work in couples (interpersonal)
g) Musical closing activity (musical intelligence-kinesthetic-interpersonal)

Naturalistic intelligence may be stimulated if instead of participating at station 5 inside the classroom or laboratory, the students have the chance to analyze natural phenomena outside of in open-air environments. Intrapersonal intelligence may be further considered.

4. Some first results

The proposed learning stations strategy was tested recently as a fundamental part of a physics education research for developing the student´s scientific observation skills. The proposal was tested within a group of 30 students at Escuela Nacional Preparatoria No. 8 “Miguel E. Schulz”, a senior high school that belongs to the UNAM. The intervention took place from February 27th until March 13th 2018. The learning stations proposal was applied within this period.

This first experience gave us some important data for a further strategy´s improvement. For example, there is a “cycle time” for completing the activities through the five learning stations. The fastest couple needed only 33 minutes, the rest of the group ended the activity approximately after a bit more than an hour. We identify the need to balance the time consumed at each station, because some station´s activities are completed “too” fast and others don´t, for example the bingo station was completed very fast causing saturation on other stations, so we need to modify the bingo activity in order to last longer and eliminate the bottle neck it causes.

As we said, the learning stations strategy was only a part of a whole didactical sequence, which was evaluated through pre-tests and post-tests results. The tests were divided in two parts, the first part was addressed to assess the improvement on the student´s scientific observation skills. The second part was focused to assess the improvement on the learning of conceptual content related with physical quantities and units, this mean, the results obtained at this second part of the pre- and post-tests are directly linked with the learning stations strategy proposed. The results have been very positive, we got a 30% improvement on the learned conceptual knowledge content.

5. Conclusions

The adequate teaching of metrology concepts, especially those related to the understanding of basic and derived physical quantities, may have important advantages for the students when learning physics. The need of scientific alphabetization expressed by Duit [16] may be achieved through an effective teaching of this topic.

As different research documents show, physics teachers must develop didactical strategies that are able to motivate the students to learn the subject, through contextualized situations, game-based learning activities and giving them the opportunity to learn with their accustomed learning style by using inclusion didactical dynamics like those allowed by the learning-station approach.

The outcome with a first practical experience applying a ludic learning-stations didactical proposal has produced some encouraging results. More research via practical cases is needed to validate the proposed methodology´s effectiveness

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